U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE

HEARING CHARTER

Implementing the Vision for Space Exploration: Development of the Crew Exploration Vehicle

Thursday, September 28, 2006
2:00 pm to 4:00 pm
2318 Rayburn House Office Building

Purpose

On Thursday, September 28th at 2:00 pm the House Committee on Science will hold a hearing to review the National Aeronautics and Space Administration's efforts to develop the Crew Exploration Vehicle (CEV), which NASA has recently announced will be called Orion. As laid out in the President's Vision for Space Exploration, Orion will carry humans to the International Space Station (ISS), the Moon, and beyond following the retirement of the Space Shuttle in 2010. On August 31st, 2006, NASA selected Lockheed Martin as its industry partner for the development and production of Orion, signing a development and production contract worth, including all options, approximately $8.1 billion through 2019.

On Wednesday the 26th of July, the Government Accountability Office (GAO) released a report critical of NASA's contracting approach for the acquisition of Orion. The report, entitled "*NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge*," faults the agency for committing to a long-term contract for Orion before reaching an appropriate level of understanding of the design and risks of the program. The GAO report says, "NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case."

Following discussions with the GAO and the Science Committee, NASA revised its then pending contract with Lockheed Martin to address some of the GAO's concerns.

NASA and Lockheed Martin have now started work under the Orion contract and expect to complete development by 2014 with a first demonstration flight occurring in 2013. Overall, NASA will be depending in part on the skills and knowledge in the contractor community to reach a final design for Orion. GAO argues that this design activity should be separated from longer-term production, allowing the government to have greater leverage to seek beneficial production terms. NASA, however, has chosen to include the entire design and production of Orion into one contract with the hopes that this will help control total life cycle costs. This hearing will explore NASA's development schedule and costs and provide a basis for ongoing oversight of this program.

Witnesses

Dr. Scott J. (Doc) Horowitz, Associate Administrator, Exploration Systems Mission Directorate, NASA

Mr. Allen Li, Director, Acquisition and Sourcing Management, Government Accountability Office

Overarching Questions

1) What is NASA's strategy for developing Orion?
2) Does NASA have the knowledge required to enter into a long-term development contract?
3) What steps can NASA take to ensure timely and cost-effective development of Orion?

Background

Following President Bush's January 14th, 2004 announcement of the Vision for Space Exploration, NASA began a number of studies to determine how the agency could implement the new direction laid out in the President's speech. The agency announced the results of its *Exploration Systems Architecture Study* (ESAS) in September, 2005 and has continued to refine this approach to date.

NASA has presented a plan designed to enable a crew of four to land anywhere on the Moon, stay for up to seven days initially, and abort and return to Earth at anytime. To enable this mission concept, NASA has chosen to separate crew and cargo using two new launch vehicles. Crew will travel aboard the Crew Exploration Vehicle, now called Orion, a capsule capable of supporting a crew of four to six. Orion will initially transport crew to the International Space Station and will eventually ferry astronauts to the Moon and back. This design will include a launch escape system that should allow the crew to safely abort in the event of a launch failure. NASA argues that this design has a safety factor many times higher than that of the current space shuttle. The capsule will launch on top of a new launch vehicle, previously described as the Crew Launch Vehicle (CLV), and which has recently been named the Ares I. This launch vehicle will use the Space Shuttle's Solid Rocket Booster (SRB) as an initial stage and an upper stage utilizing an Apollo derived engine, the J-2X. After Orion and Ares I have been developed, NASA plans to begin work on a new heavy-lift launch vehicle of a capacity slightly greater than that of the Saturn V. This vehicle, the Ares V, would launch the equipment needed to land on the Moon – equipment the CEV would link up with in low-Earth orbit. Ares V will utilize two Space Shuttle SRBs and five engines from the Boeing Delta IV, on an external tank similar to Shuttle's. NASA is calling the overall program for the development of Orion, Ares I and V, and future lunar activities the Constellation Systems program.

Issues

What has NASA committed to in the Orion development contract with Lockheed Martin?

Lockheed Martin was selected for the Orion contract on August 31, winning out over a partnership between Northrup Grumman and Boeing. The Lockheed contract is expected to cost about $3.9 billion for development and testing of two test flight capsules; it is a cost-plus contract so the exact figure cannot yet be known. The signed contract also includes two additional options, named Schedules B and C, under which NASA would contract with Lockheed to produce the operational vehicles. Schedules B and C include price ceilings for the vehicles and associated support services. The contract value of the options totals approximately $4.25 billion through 2019 assuming a schedule of five flights per year.

Initially, the contract did not make clear that Schedules B and C were options and that therefore the government could end the contract prior to production of operational vehicles without penalty. As a result of the GAO study, the contract language was changed so that it is now clear that Schedules B and C are options.

Why was Lockheed Martin chosen?

Selection documents show that NASA judged Lockheed Martin's bid superior based on cost, technical approach, and past performance.

Does NASA have the knowledge needed to sign a long-term contract?

GAO's first concern is the agency's approach of committing to a long-term contract for Orion before completing design work and developing a firmer cost estimate. GAO fears that committing now to a long-term development contract could raise costs as design changes are worked out.

Responding to the GAO report, NASA argues that it has a good sense of how the project will proceed because it is largely based on existing technology developed for the Apollo or Shuttle programs. Also, NASA points out that two teams of NASA employees conducted design studies independent of the contractor (and of the NASA teams was independent of the Constellation program). NASA also believes that making clear that Schedules B and C are merely options has also reduced the risk of cost overruns.

NASA also has included explicit milestones for the contractor to meet and given the government the ability to terminate the contract if the project is not meeting NASA's requirements.

GAO, in turn, points out that space projects in general, and NASA's in particular do not have a good record of coming in within expected costs. GAO also points out that NASA

still does not have a final design or cost estimate for Orion or Ares I. NASA has just begun the detailed design work necessary before production of the first test units. NASA expects to have preliminary designs completed by summer 2008 and final designs by spring 2010.

Why has NASA chosen a long-term contract?

NASA says it requires industry expertise to complete the design and development of Orion. While NASA is engaging all of its centers in the development projects within Constellation, the agency says it does not have sufficient personnel in critical areas to complete the designs in-house.

GAO recommended that NASA could mitigate its contract risk without delaying the project by moving forward with a contract to carry the program only through its design phase to the Preliminary Design Review (PDR) milestone, scheduled for summer 2008. During the PDR, NASA will verify that the designs for Orion meet all of the requirements for the system. At PDR, NASA (and industry) will have a much better understanding of the program and be in a stronger position to make firm commitments to cost and schedule for the development. NASA, however, has chosen to include the entire design and development of Orion into one contract with the expectation that this will help control total life-cycle costs because, among other reasons, it removes the incentive to push off expenses to later stages of the contract.

What are the technical challenges that face the Constellation Program?

NASA believes that there are no areas in the Orion concept where the technology is immature and poses significant development risks. When pressed, NASA officials have said the hardest aspect of the project will be "systems integration" – enabling elements that were originally designed for other vehicles to work together. In addition, NASA has begun focused efforts on technology areas that are currently perceived to hold the most risk, including efforts to address early risks in the thermal protection and landing systems. However, given the early stage of development of the project, the risks for the overall program are not clear. For the next year, NASA and Lockheed Martin will work to complete a set of well-defined requirements, a preliminary design, and firm cost estimates.

What is the likelihood of further technical changes to Orion?

As GAO notes in its report, NASA has made a number of significant changes to the Exploration Systems architecture since its announcement in September 2005. These include decreasing the diameter of Orion from 5.5 meters to 5 meters, moving from use of the Space Shuttle Main Engine (SSME) to an Apollo-derived engine, the J2-X, on the Ares I, and moving to the Delta IV engine on the Ares V. Further changes are expected, particularly as engine testing determines exactly how much weight the engines are capable of lifting.

What is the development timeframe for Orion and Ares I?

The NASA Authorization Act of 2005 directs NASA to launch Orion as close to 2010 as possible to minimize the time between the last Shuttle launch and the first launch of Orion. NASA had hoped to have Orion launch by 2012 – two years earlier than initially planned – but has not concluded that it will not have the funding to accomplish that.

Orion and Ares I are currently in the early stages of development. Significant design and development activities remain for both projects, including finalizing top-level requirements and drafting detailed engineering designs. This fall, both vehicles will begin System Requirement Reviews that will finalize the basic parameters of the system. Preliminary design work will be reviewed during the summer of 2008, with final reviews before commencing production occurring during the spring of 2010. NASA expects to complete a preliminary test of the first stage of Ares I in late 2009. Operational tests of the full system will not occur until fall of 2013.

Orion / Ares I	
System Requirements Review The SRR examines the functional and performance requirements defined for the system and the preliminary program or project plan and ensures that the requirements and the selected concept will satisfy the mission. SRR is typically conducted during the concept development phase following completion of the concept studies phase.	Fall 2006
Preliminary Design Review The Preliminary Design Review (PDR) demonstrates that the preliminary design meets all system requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design. It will show that the correct design option has been selected, interfaces have been identified, and verification methods have been described.	Summer 2008
Critical Design Review The purpose of the CDR is to demonstrate that the maturity of the design is appropriate to support proceeding with full scale fabrication, assembly, integration, and test, and that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet mission performance requirements within the identified cost and schedule constraints. CDR occurs near the completion of the final design phase and always before entering the fabrication, assembly, and test phase.	Spring 2010
Demonstration Flights	Fall 2013

What are the projected costs for Constellation development?

Due to the uncertainty inherent in estimating costs for development of new products, NASA develops a cost range based on past performance and cost models. Traditionally NASA has budgeted for new developments at a confidence of 50 percent, meaning that the project stood an equal chance of having an actual cost above or below the estimate. A higher confidence levels reflects a greater chance of the actual cost of a project coming in under the estimate. There is an ongoing debate within the space community about the appropriate confidence level for space acquisitions, with many critics suggesting the need

for higher confidence levels. The Air Force has recently switched to a policy of requiring estimates at the 80 percent level.

NASA predicts the Orion development effort will cost $18.3 billion from 2006 to 2020 at 65 percent confidence including both contractor and government costs. In the near term, NASA predicts that the cost of the Constellation program through 2011, when NASA would begin testing Orion and Ares I, is $32.1 billion with 80 percent confidence. Finally, NASA believes that the cost of returning to the Moon by 2018 may be around $104 billion, but NASA has not yet performed a detailed analysis of this cost. GAO estimates the total Constellation costs through 2018 total $122 billion. For Constellation, most of the development risk lies beyond the 2012 timeframe, when NASA begins work on the various craft needed to support a lunar mission.

GAO notes that the FY2007 budget does not fully support the costs laid out in the original *Exploration Systems Architecture Study* (ESAS), completed last summer. GAO estimates that NASA does not have sufficient funding budgeted to support the architecture during FY 2008, 2009, and 2010. However, NASA's approach to implementing the exploration architecture has evolved significantly since the ESAS report making it difficult to determine what shortfall may occur. NASA has continued to refine its cost estimates internally, but has embargoed that information pending the release of the FY2008 budget.

What implications would cost growth in Constellation have for other programs at NASA?

As noted by GAO, it is unclear if NASA has the budget to support the Vision as laid out in ESAS. NASA has announced its intention to carry over funds in the Exploration Systems Mission Directorate from fiscal years 2006, 2007, and 2008 to cover the expected large costs in 2009 and 2010. NASA expects to shift resources away from the shuttle program after its retirement to Constellation. Despite these resources, the agency remains challenged to support development of Orion by 2014. NASA has stated that it will pursue a lunar return program under a philosophy of "go-as-you-can-afford-to-pay." Specifically:

> NASA's plan is to contain [CEV] costs within the human space flight budget, thereby, impacting the content of other projects and programs within that budget. Thus, a higher than expected CEV cost would simply delay CEV development or production or impact other programs and projects within that human space flight budget category. NASA continues its 'go-as-you-can-afford-to-pay' strategy toward all of our missions of space exploration, scientific discovery, and aeronautics research.

The Authorization Act requires NASA to balance its human space flight, space science, Earth science, and aeronautics programs.

Witness Questions

The witnesses were asked to address the following questions in their testimony:

Dr. Scott J. Horowitz

1. What is NASA's strategy for reducing the total cost for production and operation of the CEV?
2. What actions has NASA taken to address the concerns raised in the GAO report entitled "*NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge*"?

Mr. Allen Li

1. To what degree does NASA's approach deviate from "best practices" for large system acquisitions?
2. NASA has claimed that implementing the GAO's recommendations would delay the delivery of the CEV and increase costs. Please explain why you agree or disagree with NASA's claim.
3. Does NASA have the financial resources necessary to complete the adopted acquisition strategy? What particular areas have the potential for significant cost growth?
4. What indicators would the GAO identify in order to gauge the progress of CEV development?

Appendix A: Excerpts of NASA Authorization Act of 2005 on CEV

TITLE I—GENERAL PRINCIPLES AND REPORTS

SEC. 101. RESPONSIBILITIES, POLICIES, AND PLANS.

(b) Vision for Space Exploration-

(1) IN GENERAL- The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other destinations. The Administrator is further authorized to develop and conduct appropriate international collaborations in pursuit of these goals.

(2) MILESTONES- The Administrator shall manage human space flight programs to strive to achieve the following milestones (in conformity with section 503)--

(A) Returning Americans to the Moon no later than 2020.

(B) Launching the Crew Exploration Vehicle as close to 2010 as possible.

(C) Increasing knowledge of the impacts of long duration stays in space on the human body using the most appropriate facilities available, including the ISS.

(D) Enabling humans to land on and return from Mars and other destinations on a timetable that is technically and fiscally possible.

SEC. 102. REPORTS.

(b) Budget Information- Not later than April 30, 2006, the Administrator shall transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report describing--

(1) the expected cost of the Crew Exploration Vehicle through fiscal year 2020, based on the public specifications for that development contract; and

(2) the expected budgets for each fiscal year through 2020 for human spaceflight, aeronautics, space science, and earth science--

(A) first assuming inflationary growth for the budget of NASA as a whole and including costs for the Crew Exploration Vehicle as projected under paragraph (1); and

(B) then assuming inflationary growth for the budget of NASA as a whole and including at least two cost estimates for the Crew Exploration Vehicle that are higher than those projected under paragraph (1), based on NASA's past experience with cost increases for similar programs, along with a description of the reasons for selecting the cost estimates used for the calculations under this subparagraph and the confidence level for each of the cost estimates used in this section.

SEC. 103. BASELINES AND COST CONTROLS

(a) Conditions for Development-

(1) IN GENERAL- NASA shall not enter into a contract for the development of a major program unless the Administrator determines that--

(A) the technical, cost, and schedule risks of the program are clearly identified and the program has developed a plan to manage those risks;

(B) the technologies required for the program have been demonstrated in a relevant laboratory or test environment; and

(C) the program complies with all relevant policies, regulations, and directives of NASA.

(2) REPORT- The Administrator shall transmit a report describing the basis for the determination required under paragraph (1) to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the

Senate at least 30 days before entering into a contract for development under a major program.

(3) NONDELEGATION- The Administrator may not delegate the determination requirement under this subsection, except in cases in which the Administrator has a conflict of interest.

TITLE V—HUMAN SPACE FLIGHT

SEC. 501. SPACE SHUTTLE FOLLOW-ON.

(a) Policy Statement- It is the policy of the United States to possess the capability for human access to space on a continuous basis.

(b) Progress Report- Not later than 180 days after the date of enactment of this Act and annually thereafter, the Administrator shall transmit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate describing the progress being made toward developing the Crew Exploration Vehicle and the Crew Launch Vehicle and the estimated time before they will demonstrate crewed, orbital spaceflight.

(c) Compliance Report- If, 1 year before the final planned flight of the Space Shuttle orbiter, the United States has not demonstrated a replacement human space flight system, and the United States cannot uphold the policy described in subsection (a), the Administrator shall transmit a report to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate describing--

(1) strategic risks to the United States associated with the failure to uphold the policy described in subsection (a);

(2) the estimated length of time during which the United States will not have its own human access to space;

(3) what steps will be taken to shorten that length of time; and

(4) what other means will be used to allow human access to space during that time.

SEC. 502. TRANSITION

(a) In General- The Administrator shall, to the fullest extent possible consistent with a successful development program, use the personnel, capabilities, assets, and infrastructure of the Space Shuttle program in developing the Crew Exploration Vehicle, Crew Launch Vehicle, and a heavy-lift launch vehicle.

(b) Plan- Not later than 180 days after the date of enactment of this Act, the Administrator shall transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a plan describing how NASA will proceed with its human space flight programs, which, at a minimum, shall describe--

(1) how NASA will deploy personnel from, and use the facilities of, the Space Shuttle program to ensure that the Space Shuttle operates as safely as possible through its final flight and to ensure that personnel and facilities from the Space Shuttle program are used in NASA's exploration programs in accordance with subsection (a);

(2) the planned number of flights the Space Shuttle will make before its retirement;

(3) the means, other than the Space Shuttle and the Crew Exploration Vehicle, including commercial vehicles, that may be used to ferry crew and cargo to and from the ISS;

(4) the intended purpose of lunar missions and the architecture for those missions; and

(5) the extent to which the Crew Exploration Vehicle will allow for the escape of the crew in an emergency.

SEC. 504. GROUND-BASED ANALOG CAPABILITIES

(a) Policy- It is the policy of the United States to achieve diverse and growing utilization of, and benefits from, the ISS.

(b) Elements, Capabilities, and Configuration Criteria- The Administrator shall ensure that the ISS will--

(1) be assembled and operated in a manner that fulfills international partner agreements, as long as the Administrator determines that the Shuttle can safely enable the United States to do so;

(2) be used for a diverse range of microgravity research, including fundamental, applied, and commercial research, consistent with section 305;

(3) have an ability to support a crew size of at least 6 persons, unless the Administrator transmits to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate not later than 60 days after the date of enactment of this Act, a report explaining why such a requirement should not be met, the impact of not meeting the requirement on the ISS research agenda and operations and international partner agreements, and what additional funding or other steps would be required to have an ability to support crew size of at least 6 persons;

(4) support Crew Exploration Vehicle docking and automated docking of cargo vehicles or modules launched by either heavy-lift or commercially-developed launch vehicles;

(5) support any diagnostic human research, on-orbit characterization of molecular crystal growth, cellular research, and other research that NASA believes is necessary to conduct, but for which NASA lacks the capacity to return the materials that need to be analyzed to Earth; and

(6) be operated at an appropriate risk level.

Appendix B & C:

NASA 102(b) response letter and report
NASA 103(a) response letter and report

(Will be sent separately.)